DELKIN DEVICES®

E300 Series

Industrial eUSB Module

Engineering Specification

Document Number: 401-0451-00

Revision: C

Product Overview

- **Capacity**
  - 1GB – 32GB
- **USB Interface**
  - USB 3.1 Compliant
- **Flash Interface**
  - Flash type: SLC
- **Performance**
  - Read: up to 75 MB/s
  - Write: up to 29 MB/s
- **Power Consumption**[Note1]
  - Active mode: < 125mA
  - Idle mode: < 45mA
- **MTBF**
  - More than 2,000,000 hours at 0°C
- **Features**
  - Static and Dynamic Wear Leveling
  - Bad Block Management
  - SMART
  - Firmware Update Capability
- **Temperature Range**
  - Operation: -40°C ~ 85°C
  - Storage: -50°C ~ +100°C
- **RoHS compliant**

Notes:

1. Please see “5.2 Power Consumption” for details.

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1.Introduction

1.1. General Description

Delkin's E300 Series Embedded USB (eUSB) is designed as a compact, non-removable storage module to be used as a boot device or for storage of critical data. The industrial-grade eUSB is fully compliant with USB 3.1 specifications, and is built with industrial temp SLC NAND flash.

1.2. Flash Management

1.2.1. Error Correction Code (ECC)

Flash memory cells will deteriorate with use, which might generate random bit errors in the stored data. Thus, the controller in Delkin's Industrial eUSB drive applies an advanced BCH ECC algorithm, which can detect and correct errors occur during read processes, ensuring data been read correctly, as well as protecting data from corruption. The Delkin Industrial eUSB also employs "near-miss" ECC, such that all blocks which reach a certain error threshold are automatically refreshed immediately upon detection. The threshold is determined by the specific flash and ECC configuration in the card.

1.2.2. Wear Leveling

NAND Flash devices can only undergo a limited number of program/erase cycles, and in most cases, the flash media are not used evenly. If some blocks are updated more frequently than others, the lifetime of the device would be reduced significantly. Thus, Wear Leveling techniques are applied to extend the lifespan of NAND Flash by evenly distributing write and erase cycles across the media.

The controller in Delkin's newest Industrial eUSB drive utilizes an advanced Wear Leveling algorithm, which optimizes life and performance, through a combination of static and global wear leveling. Static wear leveling is utilized until one flash reaches 90% of the rated P/E cycles, which is more efficient from a performance standpoint. Once a flash reaches 90%, wear leveling switches to a global scheme, and all flash blocks participate in wear leveling as one large pool, which enables the card to maximize lifetime.

1.2.3. Bad Block Management

Bad blocks are blocks that include one or more invalid bits and therefore, their reliability is not guaranteed. Blocks that are identified and marked as bad by the manufacturer are referred to as “Initial Bad Blocks”. Blocks that develop invalid bits during the lifespan of the flash are named “Later Bad Blocks”. The controller in Delkin’s Industrial eUSB drive implements an efficient bad block management algorithm to detect the factory-produced bad blocks and manage any bad blocks that appear with use. This practice further prevents data being stored into bad blocks and improves data reliability.

1.2.4. SMART

SMART, an acronym for Self-Monitoring, Analysis and Reporting Technology, is a special function that allows a memory device to automatically monitor its health. While there is not an industry standard for USB drive SMART functionality, as there is for SATA & PATA devices, the Delkin eUSB supports ATA pass through commands to collect data from the card. Refer to Section 7 for the command details and the information that can be extracted from the card.

1.2.5. Read Disturb Management

Delkin’s Industrial eUSB drives have advanced Read Disturb Management to prevent uncorrectable errors in heavy read applications. As flash geometries shrink, the likelihood of disturbances when adjacent pages are frequently read is increased, and typically wear leveling is triggered by writing and erasing. However, the advanced read disturb management system actually counts all reads on a block level, and compares them to a configurable threshold. Once the threshold has been reached, a read wear level is triggered and the block is refreshed, sending it to the back of the line. This ensures that errors will not accumulate to the point that they will be uncorrectable.

1.2.6. Firmware Redundancy

Since flash storage is often used in applications with unstable sources of power, protecting the firmware is critical. Delkin’s Industrial eUSB drives maintain two copies of firmware within the flash, so that if the primary copy of the firmware is damaged, the back-up copy can be used, the back-up copy is used, and then the original copy is repaired.

1.2.7. Dynamic Data Refresh

Typically, when a drive is new and less than 10% of the program/erase cycles have been consumed, the data retention time of the flash is 5 or 10 years, depending on the type of flash. At end of life, however, when 100% of the program/erase cycles have been consumed, typically, the retention time is 1 year. To extend long term data retention over the life of a card, Delkin's Industrial eUSB will automatically refresh data that is not accessed for a long time, which can be triggered based on a configurable power-on count threshold and operate in the background.

1.2.8. Power Fail Robustness

With the goal of preventing data corruption and card failure, Delkin's Industrial eUSB drives have been developed to survive unscheduled power interruptions with minimal effect. In the event of a power loss, the controller will reset and flash is immediately write-protected. A log is kept of recent flash transactions, and if the last data in the log is corrupt, then the controller will recover the latest valid entry. If a write operation was in process at the time of the power loss, but not committed to flash, or the tables had not yet been updated, then this data might be lost. Since the original data is always kept in a "twin" of the active block, we can always revert back to the last known valid state of the card.

1.2.9. Page-based Mapping

The E300 eUSB utilizes page-based mapping, which has the advantages of improved random performance, and reduced write amplification, which improves device overall life.

2.Product Specifications

2.1. Overview

- **Capacity / Flash Type**
  - 1GB to 32GB Industrial Temperature SLC

- **Electrical/Physical Interface**
  - Compliant with USB 3.1 Gen 1 Specification, which includes backward compatibility to USB 2.0 and 1.1

- **ECC Scheme**
  - Capable of correcting up to 96 bits per 1K Byte – BCH engine

- **Supports SMART commands**

- **Supports Secure Erase and Sanitize via ATA pass through commands**

- **AES encryption engine 128 and 256-bit**

- **OS Compatibility**
  - All USB 2.0 Compatible Operating Systems supported, including:
    - Windows 7 (32 & 64bit), Windows 8, Windows 10, Windows XP
    - Linux Kernel 4.2.0-27 (Ubuntu 15.10)
    - Mac OS X 10.8.4, 10.11.2

2.2. Sequential and Random Performance

Table 2-1 Performance by Capacity & Firmware Type

Capacity	Sequential		Random	
	Read (MB/s)	Write (MB/s)	Read (MB/s)	Write (MB/s)
1GB SLC	TBD	TBD	5.0	3.5
2GB SLC	TBD	TBD	5.0	3.5
4GB SLC	35	21	5.0	3.8
8GB SLC	75	35	7.0	3.5
16GB SLC	75	35	5.6	3.8
32GB SLC	TBD	TBD	5.6	3.8

Measured with CrystalDiskMark 3.0.3 64 bit in USB 3.0 mode, Random performance for 4K blocks.

2.3. Part Numbers

Industrial SLC eUSB (-40 to 85°C Operating Temperature)

Table 2-2 Part Numbers by Capacity

Capacity	Part Number
1GB	M40GTQHFL-xx000-D
2GB	M402TQHFL-xx000-D
4GB	M404TQJGR-xx000-D
8GB	M408TQJGR-xx000-D
16GB	M416TNKGR-xx000-D
32GB	M432TNJGR-xx000-D

NOTES:

1. “xx” in part number is determined by connector selection and fixed vs. removable configuration. See Section 2.4 for available options.
2. For optional Acrylic conformal coating (contact Delkin for additional cost and MOQ) to protect the devices from moisture and contaminants, replace the 000 in the part number with 050.
3. Customized parts will have a special code in place of the 000 to indicate the customer-specific features or attributes of the part.
4. Contact Delkin for information on a Security version of this product, with zone locking & encryption capabilities via an API or direct commands. NDA required.

2.4. Connector & Configuration Options

Table 2-3 Connector & Fixed/Removable Options

Code	Pitch	Total Height*	Orientation	Fixed / Removable	Connector Mfr / Part #
RA	0.100”	9.77mm	Right Angle	Removable	Sullins NPPC052KFMS-RC
R1	0.100”	5.93mm	Right Angle	Removable	Samtec HLE-105-02-G-DV
R2	2mm	6.97mm	Right Angle	Removable	Samtec MMS-105-02-L-DV
R3	2mm	4.53mm	Right Angle	Removable	Samtec CLT-105-02-G-D
R4	0.100”	5.93mm	Right Angle	Fixed Disk	Samtec HLE-105-02-G-DV
R5	2mm	6.97mm	Right Angle	Fixed Disk	Samtec MMS-105-02-L-DV
R6	2mm	4.53mm	Right Angle	Fixed Disk	Samtec CLT-105-02-G-D
R7	0.100”	9.77mm	Right Angle	Fixed Disk	Sullins NPPC052KFMS-RC
R8	0.100”	9.77mm	Right Angle	Removable No keying plug at Pin 9	Sullins NPPC052KFMS-RC
RL	0.100”	5.93mm	Right Angle	Removable External LED configuration	Samtec HLE-105-02-G-DV
ST	2mm	6.46mm	Straight	Removable	Samtec MMS-105-02-L-DH
SF	2mm	6.46mm	Straight	Fixed Disk	Samtec MMS-105-02-L-DH

*Total Height is referenced as Dimension X on the mechanical drawing in Section 7.2

Note: All connectors have keying plug at Pin 9, except R8 as noted.

3. Environmental Specifications

3.1. Environmental Conditions

3.1.1. Temperature and Humidity

- Temperature:
  - Storage: -50°C to +100°C
  - Operational: -40°C to +85°C

- Humidity:
  - RH 10 - 95% under 55°C

3.1.2. Shock & Vibration

- Shock Specification
  - 12G Sawtooth pulse, 11 ms duration, 3 axes

- Vibration Specification
  - Sine Vibration: 10Hz ~2000Hz, 16.3 G peak to peak, 3 axes
  - Random Vibration: 10Hz ~2000Hz, 1.49 GRMS, 3 axes

3.2. MTBF

MTBF, an acronym for Mean Time Between Failures, is a measure of a device's reliability. Its value represents the average time between a repair and the next failure. The measure is typically in units of hours. The higher the MTBF value, the higher the reliability of the device. The predicted result of Delkin's eUSB SSD is more than 2,000,000 hours for 0°C to 25°C operation.

3.3. Certification & Compliance

- RoHS
- USB 3.1

4.Endurance & Data Retention

Attribute	Value
Raw Flash Program/Erase Rating	60,000 cycles
TBW	Contact Delkin for TBW and life estimate based on your specific application / workload
Data Retention	10 years when P/E cycles < 10% of rated cycling 1 year when P/E cycles at 100% of rated cycling

5. Electrical Specifications

5.1. Supply Voltage

Table 5-1 Supply Voltage

Parameter	Rating
Operating Voltage	5V ± 10%

5.2. Power Consumption

Table 5-2 Power Consumption

Capacity	Read (max)	Write (max)	Idle (max)
1GB	TBD	TBD	TBD
2GB	TBD	TBD	TBD
4GB	95	90	40
8GB	125	120	45
16GB	TBD	TBD	TBD
32GB	TBD	TBD	TBD

Unit: mA

NOTES:
1. The measured input power voltage is 5V.
2. Power Consumption may vary according to flash configuration, host platform and other factors.

6.Interface

6.1. Pin Assignment and Descriptions

Table 6-1 Pin Assignment and Description for eUSB

Pin Number	eUSB Pin	Description
1	VCC	5.0V USB Bus Power Input
2	SSRX+	Superspeed Receiver
3	DM	USB 2.0 data in negative pin terminal
4	SSRX-	Superspeed Receiver
5	DP	USB 2.0 data in positive pin terminal
6	SSTX+	Superspeed Transmitter
7	GND	0V regulator ground reference input
8	SSTX-	Superspeed Transmitter
9	NC	Not Connected – Keying Plug (except R8 connector option)
10	Option	Optional External LED Connection (contact Delkin)

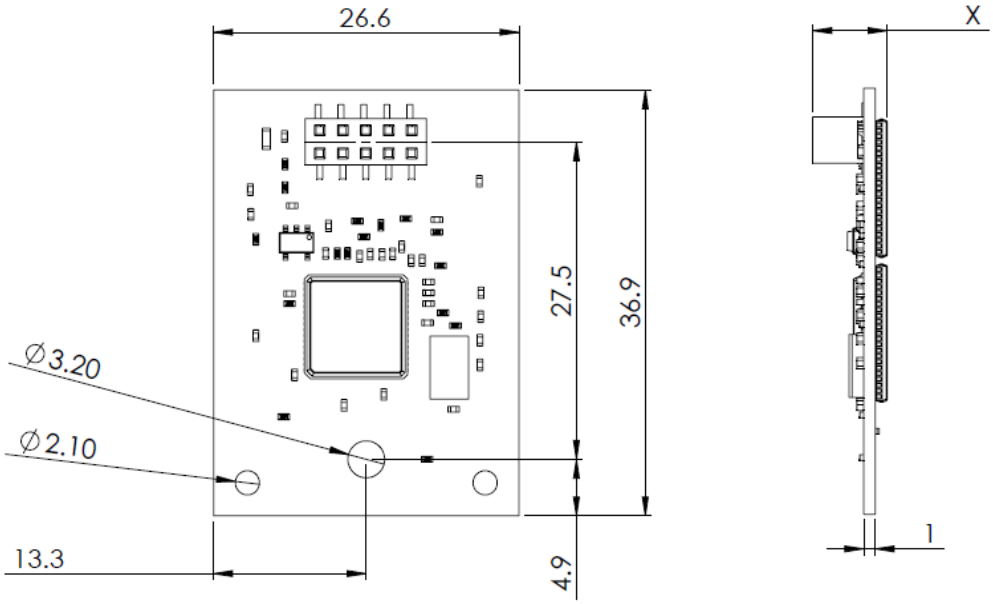
7. Physical Attributes

7.1. Mechanical Form Factor

Table 7-1 eUSB Mechanical Form Factor Attributes

Dimension	Value
Length	36.9mm ± 0.5mm
Width	26.6mm ± 0.5mm
Thickness	Varies with Connector
Center of Mounting Hole to Centerline of Connector	27.5mm ± 0.5mm
Mass	10 g (0.35 oz) maximum

7.2. Mechanical Dimensions



All dimensions in mm. Tolerance on all dimensions ± 0.5mm.

Connector Code	Total Height (Dimension X)
RA, R7, R8	9.77mm
R1, R4, RL	5.93mm
R2, R5	6.97mm
R3, R6	4.53mm
ST, SF	6.46mm

8. ATA Pass Through, IDENTIFY DEVICE & SMART

8.1. Supported Commands in ATA Pass Through

The following table lists the ATA commands that are supported by the eUSB firmware in the ATA Pass-Through(12) and ATA Pass-Through(16) commands.

No.	Comand Name	Code	FR	SC	SN	CY	DR	HD	LBA
1	Identify Device	ECh	--	--	--	--	Y	--	--
2	SMART	B0h	Y	--	--	Y	Y	--	--

Notes:
FR: Feature Register
SC: Sector Count register
SN: Sector Number register
CY: Cylinder Low/High register
DR: Drive bit of Drive/Head Register
HD: Head No. (0 to 15) of Drive/Head Register
Y: Used for the command
-- : Not used for the command

8.2. ATA Identify Device Information

The following table lists the information returned by the Identify Device ATA Passthrough command.

Word Address	Default Value	Total Bytes	Data Field Type Information
0	0040h	2	General configuration bit significant information
1 - 4	0000h	8	Reserved
5	0200h	2	Number of unformatted bytes per sector
6 - 9	0000h	8	Reserved
10-19	XXXXh	20	Serial number (20 ASCII characters)
20	0002h	2	Buffer type (dual-ported multi-sector)
21	0001h	2	Buffer size in 512 byte increments
22	0004h	2	Number of ECC bytes passed on Read/Write Long Commands
23-26	XXXXh	8	Firmware revision (8 ASCII characters)
27-46	XXXXh	40	Model number (40 ASCII characters)
47	8001h	2	Maximum 1 sector on Read/Write Multiple command
48	0000h	2	Double Word not Supported
49	0F00h	2	Capabilities: DMA, LBA, IORDY supported
50	4001h	2	Capabilities: device specific standby timer minimum
51	0200h	2	PIO data transfer cycle timing mode 2
52	0000h	2	DMA data transfer cycle timing mode not supported
53	0007h	2	Data Fields 64 to 70 and 88 are valid
54 - 58	0000h	10	Reserved
59	0101h	2	Multiple sector setting is valid
60-61	XXXXh	4	Total number of sectors addressable in LBA Mode
62	0000h	2	Single Word DMA transfer not implemented

Word Address	Default Value	Total Bytes	Data Field Type Information
63	0007h	2	Multiword DMA transfer mode, modes 0 to 2 supported
64	0003h	2	Advanced PIO modes: modes 3 and 4 supported
65	0078h	2	Minimum Multiword DMA cycle time.
66	0078h	2	Recommended Multiword DMA cycle time.
67	0078h	2	Minimum PIO transfer cycle time without flow control
68	0078h	2	Minimum PIO transfer cycle time with flow control
69-79	0000h	22	Reserved
80	01E0h	2	Major version number, ATA-5 to ATA-8 support
81	FFFFh	2	Minor version number, not reported
82	0001h	2	Command set: SMART features set
83	4000h	2	Command set: none
84	4000h	2	Command set/feature supported extension: none
85	00Xh	2	Command set enabled: SMART feature set enabled/disabled
86	0000h	2	Command set enabled: none
87	4000h	2	Command set/feature default
88	043Fh	2	UDMA modes 0 to 6 supported Selected UDMA speed depends on USB speed: SuperSpeed = UDMA6 HighSpeed = UDMA4 FullSpeed = UDMA1
89 – 118	0000h	60	Reserved
119	4000h	2	Command set/feature set supported extension: none
120	4000h	2	Command set/feature set enabled extension: none
121-129	0000h	18	Reserved
130-133	XXXXh	8	Firmware date string
134-135	0000h	4	Reserved
136-141	XXXXh	12	Firmware file name
142-147	XXXXh	12	Preformat file name
148-153	XXXXh	12	Anchor program file name
154-155	XXXXh	4	Firmware minor revision number
156-221	0000h	132	Reserved
222	1001h	2	Transport major version: Serial transport
223	FFFFh	2	Transport minor version: not reported
224-254	0000h	62	Reserved
255	XXA5h	2	Integrity Word

Words 60, 61, 85, 88 first byte, 130 – 135, 154, 155 and 255 are determined by the running firmware, all other words are configured in the preformat by the preformat host tool (hsfmt.)

8.3. ATA SMART Functionality

The ATA Pass Through module of the Delkin eUSB firmware supports the following ATA SMART commands, determined by the Feature Register value.

Value	Command
D0h	Read Data
D1h	Read Attribute Thresholds
D8h	Enable SMART Operations
D9h	Disable SMART Operations
DAh	Return Status

SMART commands with Feature Register values not mentioned in the above table are not supported and will be aborted.

8.3.1. SMART Enable Operations

COMMAND CODE: B0h with a Feature Register value of D8h

PROTOCOL: Non-data

INPUTS:

Register	7	6	5	4	3	2	1	0
Features	D8h							
Sector Count								
Sector Number								
Cylinder Low	4Fh							
Cylinder High	C2h							
Device/Head	1	1	1	0				
Command	B0h							

NORMAL OUTPUTS: None required.

ERROR OUTPUTS: Aborted if the signature in the Cylinder registers is invalid.

DESCRIPTION: This command enables access to the SMART capabilities of the eUSB controller firmware. The state of SMART (enabled or disabled) is preserved across power cycles.

8.3.2. SMART Disable Operations

COMMAND CODE: B0h with a Feature Register value of D9h

PROTOCOL: 5Ah

INPUTS:

Register	7	6	5	4	3	2	1	0
Features	D9h							
Sector Count								
Sector Number								
Cylinder Low	4Fh							
Cylinder High	C2h							
Device/Head	1	1	1	0				
Command	B0h							

NORMAL OUTPUTS: None required.

ERROR OUTPUTS: Aborted if either the signature in the Cylinder registers is invalid or if SMART is not enabled.

DESCRIPTION: This command disables access to the SMART capabilities of the eUSB controller firmware. The state of SMART (enabled or disabled) is preserved across power cycles.

8.3.3. SMART Read Data

COMMAND CODE: B0h with a Feature Register value of D0h

PROTOCOL: PIO data in.

INPUTS:

Register	7	6	5	4	3	2	1	0
Features	D0h							
Sector Count								
Sector Number								
Cylinder Low	4Fh							
Cylinder High	C2h							
Device/Head	1	1	1	0				
Command	B0h							

NORMAL OUTPUTS: None required.

ERROR OUTPUTS: Aborted if the signature in the Cylinder registers is invalid or if SMART is not enabled.

DESCRIPTION: This command returns one sector of SMART data. The data structure returned is shown in Section 3.4.

8.3.4. SMART Data Structure

The following 512 bytes make up the device SMART data structure. Users can obtain the data using the “SMART Read Data” command (D0h.)

Byte	F / V	Description
0 – 1	0010h	SMART structure version
2 – 361		Attribute entries 1 to 30 (12 bytes each)
362	00h	Off-line data collection status (no off-line data collection)
363	00h	Self-test execution status byte (self-test completed)
364 – 365	0000h	Total time in seconds to complete off-line data collection activity
366	00h	--
367	00h	Off-line data collection capability (no off-line data collection)
368 – 369	0003h	SMART capability
370	00h	Error logging capability (no error logging)
371	00h	--
372	00h	Short self-test routine recommended polling time (in minutes)
373	00h	Extended self-test routine recommended polling time (in minutes)
374 – 385	00h	Reserved
386 – 387	0042h	SMART Structure Version
388 – 391		Firmware “Commit” Counter
392 - 395		Firmware Wear Level Threshold
396	01h	Global Wear Leveling Active
397	01h	Global Bad Block Management active
398 – 401		Average Flash Block Erase Count
402 – 405		Number of Flash Blocks involved in Wear Leveling
406 – 409		Number of total ECC errors during firmware initialization
410 – 413		Number of correctable ECC errors during firmware initialization
414 - 510	00h	-
511		Data structure checksum

The attributes that are defined for the eUSB firmware return their data in the attribute section of the SMART data, using a 12 byte data field.

The field at offset 386 gives a version number for the contents of the SMART data structure. For the controller in the Delkin eUSB, only version 4 is defined.

The byte at offset 396 is fixed to 1 for page-based firmware. All chips within an interleaved channel are used for wear leveling.

The byte at offset 397 is fixed to 1 for page-based firmware. Bad block management is always done within all chips of an interleaved channel.

8.3.5. Spare Block Count Attribute

This attribute gives information about the amount of available spare blocks.

Offset	Value	Description
0	196	Attribute ID – Reallocation Count
1 – 2	0003h	Flags – Pre-fail type, attribute value is updated during normal operation
3		Attribute value. The value returned here is the percentage of remaining spare blocks summed over all flash chips, i.e. (100 x current spare blocks / initial spare blocks)
4		Attribute value (worst value)
5 – 7		Sum of the initial number of spare blocks for all flash chips
8 – 10		Sum of the current number of spare blocks for all flash chips
11	00h	Reserved

This attribute is used for the SMART Return Status command. If the attribute value field is less than the spare block threshold (currently fixed at 10), the SMART Return Status command will indicate a threshold exceeded condition.

8.3.6. Spare Block Count Worst Chip Attribute Threshold

This attribute gives information about the amount of available spare blocks on the interleave channel that has the lowest current number of spare blocks.

Offset	Value	Description
0	213	Attribute ID – Spare Block Count Worst Channel (vendor specific)
1 – 2	0003h	Flags – Pre-fail type, attribute value is updated during normal operation
3		Attribute value. The value returned here is from all interleaved channels the worst percentage of remaining spare blocks i.e. (100 * current spare blocks / initial spare blocks).
4		Attribute value (worst value)
5 – 7		Initial number of spare blocks of the interleave channel with the lowest current number of spare blocks
8 – 10		Current number of spare blocks of the interleave channel with the lowest current number of spare blocks
11	00h	Reserved

8.3.7. Erase Count Attribute

This attribute gives information about the amount of flash block erases that have been performed.

Offset	Value	Description
0	229	Attribute ID – Erase Count Usage (vendor specific)
1 – 2	000Xh	Flags – Pre-fail or Advisory type, attribute value is updated during normal operation
3		Attribute value. The value returned here is an estimation of the remaining card life, in percent, based on the number of flash block erases compared to the target number of erase cycles per block.
4		Attribute value (worst value)
5 – 10		Estimated total number of block erases.
11	00h	Reserved

This attribute is used for the SMART Return Status command. If the attribute value field is less than the erase count threshold (currently fixed at 10), the SMART Return Status command will indicate a threshold exceeded condition.
The target number of erase cycles per flash block is taken from the MaxBlockEraseCount column in the Device Description file.

8.3.8. Total ECC Errors Attribute

This attribute gives information about the total number of ECC errors that have occurred on flash read commands during firmware runtime. This attribute is not used for the SMART Return Status command.

Offset	Value	Description
0	203	Attribute ID – Number of ECC Errors
1 – 2	0002h	Flags – Advisory type, attribute value is updated during normal operation
3	64h	Attribute value. This value is fixed at 100.
4	64h	Attribute value (worst value)
5 – 8		Total number of ECC errors (correctable and uncorrectable)
9 – 10		---
11	00h	Reserved

8.3.9. Correctable ECC Errors Attribute

This attribute gives information about the total number of correctable ECC errors that have occurred on flash read commands during firmware runtime. This attribute is not used for the SMART Return Status command.

Offset	Value	Description
0	204	Attribute ID – Number of corrected ECC Errors
1 – 2	0002h	Flags – Advisory type, attribute value is updated during normal operation
3	64h	Attribute value. This value is fixed at 100.
4	64h	Attribute value (worst value)
5 – 8		Total number of correctable ECC errors
9 – 10		---
11	00h	Reserved

8.3.10. Total Number of Reads Attribute

This attribute gives information about the total number of flash read commands. This can be useful for interpretation of the number of correctable or total ECC errors. This attribute is not used for the SMART Return Status command.

Offset	Value	Description
0	232	Attribute ID – Number of Reads (vendor specific)
1 – 2	0002h	Flags – Advisory type, attribute value is updated during normal operation
3	64h	Attribute value. This value is fixed at 100.
4	64h	Attribute value (worst value)
5 - 10		Total number of flash read commands
11	00h	Reserved

8.3.11. Power On Count Attribute

Offset	Value	Description
0	12	Attribute ID – Power On Count (vendor specific)
1 – 2	0002h	Flags – Advisory type, attribute value is updated during normal operation
3	64h	Attribute value. This value is fixed at 100.
4	64h	Attribute value (worst value)
5 - 8		Number of Power On cycles
9 – 10		---
11	00h	Reserved

8.3.12. Total LBAs Written Attribute

This attribute gives the total amount of data written to the disk, in units of 32MB (65536 sectors.) This number can be converted to Terabytes Written (TBW) by dividing the raw attribute value by 2^{15}.

Offset	Value	Description
0	241	Attribute ID – Total LBAs Written (vendor specific)
1 – 2	0002h	Flags – Advisory type, attribute value is updated during normal operation
3	64h	Attribute value. This value is fixed at 100.
4	64h	Attribute value (worst value)
5 - 10		Total number of LBAs written to the disk, divided by 65536
11	00h	Reserved

8.3.13. Total LBAs Read Attribute

This attribute gives the total amount of data read from the disk, in units of 32MB (65536 sectors.) This number can be converted to Terabytes read by dividing the raw attribute value by 2^{15}.

Offset	Value	Description
0	241	Attribute ID – Total LBAs Read (vendor specific)
1 – 2	0002h	Flags – Advisory type, attribute value is updated during normal operation
3	64h	Attribute value. This value is fixed at 100.
4	64h	Attribute value (worst value)
5 - 10		Total number of LBAs read from the disk, divided by 65536
11	00h	Reserved

8.3.14. Anchor Block Status Attribute

This attribute reports how many times the Anchor block of the card has been re-written, either by the Anchor block repair routine, or by a firmware update.

Offset	Value	Description
0	214	Attribute ID – Anchor Block Status (vendor specific)
1 – 2	0002h	Flags – Advisory type, attribute value is updated during normal operation
3	64h	Attribute value. This value is fixed at 100.
4	64h	Attribute value (worst value)
5 – 8		Anchor Block Write Count
9 – 10		---
11	00h	Reserved

8.3.15. Trim Status Attribute

This attribute gives percent ratio for the disk space that is currently in the trimmed state.

Offset	Value	Description
0	215	Attribute ID – Trim Status (vendor specific)
1 – 2	0002h	Flags – Advisory type, attribute value is updated during normal operation
3		Attribute value.
4		Attribute value (worst value)
5 - 10		---
11	00h	Reserved

8.3.16. SMART Read Attribute Thresholds

COMMAND CODE: B0h with a Feature Register value of D1h

PROTOCOL: PIO data in.

INPUTS:

Register	7	6	5	4	3	2	1	0
Features	D1h							
Sector Count								
Sector Number								
Cylinder Low	4Fh							
Cylinder High	C2h							
Device/Head	1	1	1	0				
Command	B0h							

NORMAL OUTPUTS: None required.

ERROR OUTPUTS: Aborted if the signature in the Cylinder registers is invalid or if SMART is not enabled.

DESCRIPTION: This command returns one sector of SMART attribute thresholds. The data structure returned is:

Offset	Value	Description
0 - 1	001h	SMART structure version
2 – 361		Attribute threshold entries 1 to 30 (12 bytes each)
362 – 379	00h	Reserved
380 – 510	00h	---
511		Data structure checksum

8.3.17. Spare Block Count Attribute Threshold

Offset	Value	Description
0	196	Attribute ID – Reallocation Count
1	0Ah	Spare Block Count Threshold, fixed at 10
2 - 11	00h	Reserved

8.3.18. Spare Block Count Worst Channel Attribute Threshold

Offset	Value	Description
0	213	Attribute ID – Spare Block Count Worst Channel (vendor specific)
1	0Ah	Spare Block Count Worst Channel Threshold, fixed at 10
2 - 11	00h	Reserved

8.3.19. Erase Count Attribute Threshold

Offset	Value	Description
0	229	Attribute ID – Erase Count Usage (vendor specific)
1	0Ah	Erase Count Threshold, fixed at 10
2 - 11	00h	Reserved

8.3.20. Total ECC Errors Attribute Threshold

Offset	Value	Description
0	203	Attribute ID – Number of ECC errors
1	00h	No threshold for the Total ECC Errors Attribute
2 - 11	00h	Reserved

8.3.21. Correctable ECC Errors Attribute Threshold

Offset	Value	Description
0	204	Attribute ID – Number of corrected ECC errors
1	00h	No threshold for the Correctable ECC Errors Attribute
2 - 11	00h	Reserved

8.3.22. UDMA CRC Errors Attribute Threshold

Offset	Value	Description
0	199	Attribute ID –UDMA CRC error rate
1	00h	No threshold for the UDMA CRC Errors Attribute
2 - 11	00h	Reserved

8.3.23. Total Number of Reads Attribute Threshold

Offset	Value	Description
0	232	Attribute ID – Number of Reads (vendor specific)
1	00h	No threshold for the Total Number of Reads Attribute
2 - 11	00h	Reserved

8.3.24. Power On Count Attribute Threshold

Offset	Value	Description
0	12	Attribute ID – Power On Count
1	00h	No threshold for the Power On Count Attribute
2 - 11	00h	Reserved

8.3.25. Total LBAs Written Attribute Threshold

Offset	Value	Description
0	241	Attribute ID –Total LBAs Written (vendor specific)
1	00h	No threshold for the Total LBAs Written Attribute
2 - 11	00h	Reserved

8.3.26. Total LBAs Read Attribute Threshold

Offset	Value	Description
0	242	Attribute ID – Total LBAs Read (vendor specific)
1	00h	No threshold for the Total LBAs Read Attribute
2 - 11	00h	Reserved

8.3.27. Anchor Block Status Attribute Threshold

Offset	Value	Description
0	214	Attribute ID – Anchor Block Status (vendor specific)
1	00h	No threshold for the Anchor Block Status Attribute
2 - 11	00h	Reserved

8.3.28. Trim Status Attribute Threshold

Offset	Value	Description
0	215	Attribute ID – Trim Status (vendor specific)
1	00h	No threshold for the Trim Status Attribute
2 - 11	00h	Reserved

8.3.29. SMART Return Status

COMMAND CODE: B0h with a Feature Register value of DAh

PROTOCOL: Non-data

INPUTS:

Register	7	6	5	4	3	2	1	0
Features	DAh							
Sector Count								
Sector Number								
Cylinder Low	4Fh							
Cylinder High	C2h							
Device/Head	1	1	1	0				
Command	B0h							

NORMAL OUTPUTS: Returns a status indication as described below.

ERROR OUTPUTS: Aborted if the signature in the Cylinder registers is invalid or if SMART is not enabled.

DESCRIPTION: This command checks the device reliability status. If a threshold exceeded condition exists for either the Spare Block Count Worst Channel attribute or the Erase Count attribute, the device will set the Cylinder Low register to F4h and the Cylinder High register to 2Ch. If no threshold exceeded condition exists, the device will set the Cylinder Low register to 4Fh and the Cylinder High register to C2h.

WARNING: This product may contain chemicals known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to www.p65warnings.ca.gov.